# NASA STTR 2014 Phase I Solicitation

## T12 Materials, Structures, Mechanical Systems and Manufacturing

Materials, Structures, Mechanical Systems, and Manufacturing This topic is extremely broad, covering five technology areas: materials, structures, mechanical systems, manufacturing, and cross-cutting technologies. The topic consists of enabling core disciplines and encompasses fundamental new capabilities that directly impact the increasingly stringent demands of NASA science and exploration missions.

# Subtopics

### T12.01 High Fidelity Predictions for Spacecraft and Launch Vehicle Vibroacoustic Environments and Coupling

**Lead Center: LaRC**

**Participating Center(s): MSFC, SSC**

Fully verified and validated physics-based methods are desired to predict aero-acoustic and buffet loads experienced by launch vehicles and the resulting structural response. Prediction improvements in both the external environments and transmitted internal vibration are needed to better design lighter and cheaper spacecraft and launch vehicle structure as well as lower costs associated with ruggedizing and qualifying spacecraft and launch vehicle secondary structures. New methods are needed to improve environment predictions in terms of absolute levels, spatial definition including cross-spectra, and associated dispersions. Innovations in the following specific areas are solicited:

- Fundamental physics based CFD predictions of the flow over compression and expansions corners and protuberances and the resulting fluctuating pressure loads.
- Wind tunnel and/or flight tests to provide validation data of the cross spectra dynamic loads for the above problem areas and for the influence of protuberance disturbed pressure fields on vibration.
- Innovative approaches to measure full spectrum surface loads over broad areas to 8kHz full scale.
- New techniques to measure and predict rocket plume-induced fluctuating pressure loads.
- Concepts to accurately and efficiently couple these loads to realistic launch vehicle structures.
- Improved deterministic and statistical modeling of the loads and resulting vibration and transmission.
- Improved integration of vibro-acoustic design criteria into early structural design to provide more effective trade-off studies.

## T12.02 High Temperature Materials and Sensors for Propulsion Systems

**Lead Center: GRC**

**Participating Center(s): AFRC, ARC, LaRC, MSFC, SSC**

Advanced high temperature materials, structures and sensors are crosscutting technologies which are essential in the design, development and health maintenance/detection needs of components and subsystems that will be needed in future generations of aeronautical and space propulsion systems. The extreme temperature and environmental stability requirements posed by aerospace propulsion systems requires material improvements to meet the challenges of systems of the future. Increased temperature capability can be achieved through the development of new and improved materials as well as through innovative designs, with both materials and designs dependent on advanced processing techniques. The combined effect of environment plus mechanical/thermal loading is expected to have a greater degree of influence on the durability of aerospace high temperature materials. Nanotechnology offers a means to develop higher-temperature/environmentally-resistant structural materials with engineered microstructures that can optimize material properties for propulsion hot section components. Multifunctional materials and structures offer a means to reduce component weight in aerospace flight vehicles, enabling efficiency, performance improvements and reduced fuel burn for aircraft and greater payload mass and launch cost reduction for spacecraft. The small volume and high force-to-weight ratio of shape memory alloys are an attractive actuator replacement for current ones based on electric motors, hydraulic or pneumatic systems. Sensing methods and measurement techniques that are cost-effective and reliably assess the health of aerospace engines and vehicle components in harsh high-temperature environments (to 3000 °F) allow for a proactive approach to maintain capability and safety. Proposals are sought to:

- Develop innovative approaches to enhance the processability, performance and reliability of advanced high temperature materials, including metals, ceramics, polymers, high-strength fibers, composites, hybrids and coatings to improve environmental durability for engine components.
- Develop innovative methods, evaluate and model the impact on the mechanical properties of representative aerospace materials tested while resident in the extreme application environment, to compare to mechanical property testing in air or in vacuum.
- Demonstrate novel processing approaches (simpler, more cost effective) for advanced aerospace materials for propulsion systems.
- Develop physics-based modeling tools to predict durability and life based on damage mechanisms of advanced materials.

## T12.03 Additive Manufacturing of metal Plus Insulator Structures with sub-mm Features

**Lead Center: GSFC**

NASA is interested in investigating additive manufactured structures combining metals and insulators demonstrating multiple layers of 10-500 um lines and spaces, 200 um thick insulator layers, and 200 um diameter blind vias on 400 um centers capable of withstanding ~800 V between layers.

Expected Deliverables: Fabrication of a small area, few $cm^2$, micro-well detector with 200 um diameter holes, 200 um deep, on 400 um centers that operates up to ~800 V. Demonstration of scalability to large, ~1 $m^2$, area.

Mission Traceability: The Advanced Energetic Pair Telescope (AdEPT), a medium energy gamma-ray polarimeter.

Beyond the initial medium-energy gamma-ray instrument application, NASA foresees a wide range of further scientific space instruments enabled by additive manufacturing (3-D printing) that combines metals and insulators with sub-mm feature sizes. Possibilities include fabrication of electro-mechanical structures for ionization detectors, mass spectrometers, charged particle detectors et cetera for both small and large scale space missions.

In addition, this is a generic technology which would also be suitable for fabrication of commercial grade, micro-scale electronics.

State of the Art: Additive manufacturing with metals or insulators (plastics) is advancing rapidly. SOA is limited in feature size, inability to combine metals and insulators, and surface smoothness needed for high voltage applications. 3-D additive manufacturing that combines insulators and conductors is being pursued by several entities. Combining metals and insulators with sub-mm features would provide significant improvements in performance and size of the micro-well detectors for AdEPT. Current micro-well fabrication using laser micro-machining requires RIE post processing to eliminate residue from laser ablation that leads to high voltage breakdown in the micro-wells.

### T12.04 Experimental and Analytical Technologies for Additive Manufacturing

**Lead Center: MSFC**

**Participating Center(s): ARC, GRC, JSC, LaRC**

Additive manufacturing is becoming a leading method for reducing costs, increasing quality, and shortening schedules for production of innovative parts and component that were previously not possible using more traditional methods of manufacturing.  In the past decade, methods such as selective laser melting (SLM) have emerged as the leading paradigm for additive manufacturing (AM) of metallic components, promising very rapid, cost-effective, and on-demand production of monolithic, lightweight, and arbitrarily intricate parts directly from a CAD file.  In the push to commercialize the SLM technology, however, the modeling of the AM process and physical properties of the resulting artifact were paid little attention.  As a result, commercially available systems are based largely on hand-tuned parameters determined by trial and error for a limited set of metal powders. The system operation is far from optimal or efficient, and the uncertainty in the performance of the produced component is too large.  This, in turn, necessitates a long and costly certification process, especially in a highly risk-aware community such as aerospace.

This topic seeks technologies that close top technology gaps in both experimental and analytical areas in materials design, process modeling and material behavior prediction to reduce time and cost for materials development and process qualification for SLM:

- Additive Manufacturing Technologies: Develop real-time additive manufacturing process monitoring for real-time material quality assurance prediction; Finish inspection and qualification of parts for implementation, replacement, and repair; Develop standards for accepting additively manufactured parts for use in space systems.
- Research-grade test beds: Experimental test beds that will allow for detailed study of individual phases of the SLM and other methods of additive manufacturing by NASA scientists, academic groups, etc. (Affordability of test bed will be crucial for fostering a large community of developers for next-generation SLM/AM systems.)
- Physics-based models: Reduced-order physics models for individual phases of additive manufacturing techniques, mainly to enable rapid processing of process data and to facilitate model-based optimal process control. (Note that most, if not all, phases of the SLM cycle requires coupled multi-physics modeling.)
- Analytical Tools: Develop analytical tools to understand effects of process variables on materials evolution to insure expected material microstructure and apply to certification of manufacturing process.
- Digital models: Standardize the use of structured light scanning or equivalent within manufacturing processes; model-based design environment where manufacturing does not rely on both models and drawings for data; standard paperless manufacturing execution system; digital fabrication machines that combine additive, subtractive, and other multi-axial material transformation processes.
- Numerical simulation codes:  Software for high-fidelity simulation of various SLM phases for guiding the development, and enabling the subsequent verification, of new analytical physics models.

Mission Traceability - STMD continues to seek manufacturing techniques and capabilities that will allow missions of increased capability and reduced costs. Manufacturing technologies have high value and make a significant contribution to the interests of others outside of NASA, specifically those that address broader national needs as well as the needs of the commercial space industry.

State of the Art - Advanced Manufacturing is rapidly evolving, and newer technologies are emerging.  The first in-space 3-D print experiment will fly in 2014, and related technologies will follow exponentially.